3.10 DEEP BOREHOLE COMPLEX SITE (GENERIC)

Deep borehole-like waste storage facilities currently do not exist in the United States, and no actual sites for drilling a deep borehole have been proposed. Therefore, the approach to describing the environmental setting for the deep borehole is to provide a range of existing or probable environmental conditions. These conditions, to the extent possible, are determined from existing information about typical locations at either end of the range of conditions. It is assumed that these conditions, at either end of the range adequately represent the actual range of conditions. In developing a generic environmental baseline for the deep borehole site, a set of assumptions was used to help define where such a facility could be developed. The major assumptions were the following: (1) the site would be located within the contiguous United States in geologically stable Precambrian crystalline rocks; (2) the site would be located distant from international borders and any population centers; (3) the site would have reasonable access to water supplies, electrical power, and ground transportation; and (4) the site would be located so that surface waters could be sufficiently protected from construction activities and facility operations.

The optimum geographic location for a deep borehole site is an area far removed from major drainage, lakes, oceans, and areas of low population density. The topographic relief is minimal in order to provide a low differential head in groundwater. The area in the immediate vicinity of the deep borehole site is large enough to accommodate several drill sites, as previously described in Section 2.4.3, while avoiding steep surface water drainage gradients that would allow rapid distribution of contaminants in case of an accident.

The long-term performance of the deep borehole system depends primarily on the geologic system. Therefore, the most important factor that must be considered in the selection of an optimum borehole site is hydrologic isolation from the biosphere for geologic times. To achieve this degree of hydrologic isolation, the host rock must have very low matrix permeability. In addition, the locality should be in an area of low seismicity to indicate stable geology, where a possible return of glacial or pluvial climate will not cause a significant change in surface water or groundwater systems, and where there is no danger of exhumation by erosion.

An example of the low or completely undeveloped end of the range of existing conditions could be forests, grazing lands, agricultural areas, or federally owned land with almost no permanent facilities. Given the proper geologic and hydrologic conditions, and access to the transportation infrastructure, these types of areas could represent the undeveloped site in the range of environmental settings. Other locations that could be selected for a borehole site could be located in more developed areas. At the developed end of the range of environmental settings, a deep borehole site could resemble any one of the DOE sites previously described.

Should this alternative be selected, a siting study would be conducted, in addition to identifying site-specific environmental conditions and impacts in a tiered NEPA document.

3.10.1 LAND RESOURCES

The approach to defining the environmental setting for land resources is not site-specific. Consequently, a range of land-use and visual resources conditions that could exist at potential deep borehole complex site locations has been provided (see Table 3.10.1–1).

Table 3.10.1–1. Land Resources Attributes of the Generic Deep Borehole Complex Site

Land Use Attributes	
Land Area	2,000 - 20,000 ha
Land Ownership	Public or private
Existing Land Use	
Onsite	Undeveloped agricultural or industrial
Offsite	Undeveloped and/or agricultural
Land Use Compatibility	Likely
Plans, Policies, and Controls	
Jurisdiction	Federal, State, local
Enforcement	Lax to stringent
Conformance	Site-dependent
Visual Resource Attributes	
Landscape Character	
Site	Gentle relief
Viewshed	Undeveloped to agricultural
Visual Resource	
Sensitivity Level	Low to medium to high
Distance zones	Foreground, middleground, background, and seldom-seen
BLM VRM class	3 to 5
Degree of contrast	Weak to moderate

Source: LLNL 1996a.

Land Use. The potential site would require at least 2,000 ha (5,000 acres) of land area to accommodate the facility and buffer zone. The potential site could be located on public or private lands ranging up to 20,000 ha (49,420 acres). If the borehole site were located on privately-owned land, it would likely require the low to middle range of land area. If the site were located on publicly owned land (Federal, State, or local), the borehole could be part of a much larger site and could require the upper range of this land area. The range of site existing land uses would likely be undeveloped, agricultural, or industrial. Therefore, a change in site land use could occur. It is likely that land uses within the immediate vicinity of the site would range from undeveloped to agricultural (for example, cropland and grazing land) use. Due to the 1.6-km (1-mi) buffer zone surrounding the facility, it is likely that incompatibility, if any, with adjacent offsite land use would be minimized. Depending upon location, use, ownership, or management, the site could be subject to a variety of land-use plans, policies, and controls at the Federal, State, or local level. The existence and the stringency of these land-use plans, policies, and controls vary by jurisdiction. Regulations governing the type, density, and location of development are traditionally applied at the municipal (local) level through the comprehensive plan and its implementing mechanism, the zoning ordinance. Development of a privately owned site could require a change in the existing zoning classification. Development of a publicly owned site would likely conform to existing site development plans. If adjacent lands or lands that could be impacted by site development are designated as special status lands (for example, prime farmland, wild and scenic river, or wilderness study area), site development could be subject to additional controls.

Visual Resources. The complex would likely be constructed on a very small portion of the total site area. The immediate viewshed would likely range from undeveloped (for example, meadow and forest land) to agricultural lands. As discussed in Section 3.1.1, a visual resource inventory is comprised of three factors: scenic quality, distance zones, and sensitivity levels. Area sensitivity levels could range from low to high. Potential high visual sensitivity areas that could be impacted by the facilities include nearby public roadways, residential areas, and recreational/scenic areas with high user volumes. However, nearby public roadways predominately used by site workers could have a lower sensitivity level, while sensitivity levels would likely range from medium to high if nearby roads are traveled by the general public. The full range of distance zones could occur. Due to the mandatory 1.6-km (1-mi) buffer zone, it is probable that views of the facilities would predominately fall into the middleground zone. Therefore, it is likely that the degree of contrast would range from weak to moderate and that the overall visual character of the site would be consistent with a BLM VRM classification ranging from Class 3 to Class 5.

3.10.2 SITE INFRASTRUCTURE

Baseline Characteristics. The generic deep borehole site could have the baseline site infrastructure characteristics within the ranges shown in Table 3.10.2–1.

Table 3.10.2–1. Generic Deep Borehole Complex Site Baseline Characteristics

Characteristics	Site Availability
Transportation	
Roads (km)	0 to 60
Railroads (km)	0 to 20
Electrical	
Energy consumption (MWh/yr)	6,500 to 12,000
Peak load (MWe)	2 to 1,000
Fuel	
Natural gas (m^3/yr)	0 to 5,000,000
Oil (million l/yr)	0 to 100
Coal (t/yr)	0 to 200,000
Steam (kg/hr)	0 to 150,000

Source: HF DOE 1990e; INEL 1993a:5; NTS 1993a:4; OR LMES 1996i; PX 1995a:1; PX DOE 1995d; PX DOE 1996b; SRS 1993a:3.

The generic deep borehole site would be expected to be mostly open vacant land with a few widely scattered facilities. Any existing facilities would not likely be useful for the functions required in the deep borehole complex, but could possibly coexist with the developed borehole site.

The transportation infrastructure could be nonexistent on the site or could be well developed. However, the site would have reasonable access to transportation nodes with some new construction of access roads and railroad lines. There would be no surface water transportation in the vicinity.

Electricity, telecommunications, and other utilities may be available to the generic deep borehole site before development of the site. These utilities could be connected to the site or generated at the site, depending on the offsite availability. It is expected that the nearest electric utility company would be able to provide the modest borehole electricity requirements with little effect on the utility or sub-regional power pool. Typical ranges of capabilities of sub-regional power pools are shown in Table 3.10.2–2.

Natural gas, diesel, liquid propane fuel, and coal would be available from local utilities or suppliers either by pipelines or surface transportation to the borehole site.

Table 3.10.2–2. Generic Deep Borehole Complex Site Sub-Regional Power Pool Electrical Summary

Characteristics	Energy Production
Type Fuel[a]	
Coal	14 to 59%
Nuclear	0 to 39%
Hydro/geothermal	2 to 46%
Oil/gas	<1 to 32%
Other[b]	0 to 30%
Total Annual Production	107,607,000 to 272,155,000 MWh
Total Annual Load	104,621,000 to 293,262,000 MWh
Energy Exported Annually[c]	-45,400,000 to 6,359,000 MWh
Generating Capacity	24,870 to 61,932 MWe
Peak Demand	20,578 to 57,028 MWe
Capacity Margin[d]	4,064 to 13,655 MWe

[a] Percentages do not total 100 percent due to rounding.
[b] Includes power from both utility and nonutility sources.
[c] Energy exported is not the difference of production and load due to pumped storage.
[d] Capacity margin is the amount of generating capacity available to provide for scheduled maintenance, emergency outages, system operating requirements, and unforeseen electrical demand.

Source: NERC 1993a.

3.10.3 AIR QUALITY AND NOISE

Meteorology and Climatology. The meteorological and climatological conditions for the generic deep borehole site include the range of extremes in ambient temperature, windspeed and direction, and precipitation exhibited over the United States. A generic deep borehole site could exhibit a wide diversity of climatology. Therefore, no further description of meteorology and climatology has been provided with respect to a generic deep borehole site.

Ambient Air Quality. Ambient air quality conditions for the generic deep borehole site include a wide range of pollutants and conditions. Some areas do not yet meet the ambient standards for certain pollutants. Areas with air quality better than the NAAQS are designated as being in attainment; areas with worse air quality are designated as nonattainment areas. Nonattainment areas could be less desirable for a deep borehole site since more restrictive requirements would apply for pollutants for which the area is nonattaining.

Noise. Specific existing noise sources and characteristics of a generic deep borehole site cannot be described. However, it is expected that such a site would be essentially rural in character and would have typically low background sound levels. Typical DNL in the range 35 to 50 dBA (EPA 1974a:B-4) can be expected for such a rural location where noise sources may include wind, insect activity, aircraft, and agricultural activity. An area that is essentially uninhabited can be expected to have lower sound levels, with the major sources of noise possibly including an occasional airplane and natural physical phenomena such as wind, rain, and wildlife activities.

3.10.4 WATER RESOURCES

Surface Water. Availability of water is location-specific and depends on the hydrology and constraints of the local area. The availability of water supplies can be characterized by precipitation. In areas where rainfall is abundant and population is dense, water supply is commonly obtained from local surface water reservoirs and shallow wells. In arid climates, water supply is commonly obtained from deep wells and manmade lakes created by damming major rivers. In humid climates, water supply is generally derived from surface water taken from major waterways. Local constraints include seasonal fluctuations in precipitation, with drought being an extreme example; consumption by other facilities using the same water supply; and State regulations, such as water appropriation permit requirements.

Water required for construction and operation activities may not be available to the generic deep borehole site before development of the site, depending on the site location. Water could be generated or delivered to the deep borehole site, either by pipelines or surface transportation, depending on the availability from offsite suppliers.

Surface water drainage areas could range in size from 0 to 3,200 km^2 (0 to 1,235 mi^2). Surface water resources discharge rates could range from 0 to 3,360 m^3/s (0 to 118,642 ft^3/s). Surface water reservoir storage capacity could range from 0 to 49 trillion l (0 to 13 trillion gal).

Site drainage of the generic deep borehole site must comply with the regulations of the local governing agency. The minimum design level for the Storm Water Management System is the 25-year, 6-hour storm, but potential effects of larger storms up to the 100-year, 6-hour storm would also be considered for site evaluation.

In the vicinity of the generic deep borehole site, surface water classifications could range from none (no surface water near the site) to fresh water suitable for fishing, swimming, and other primary and secondary contact recreation, and also as an existing or potential source of potable water.

The deep borehole site would be located in an area above the critical flood elevation (as determined from maps and site studies) of the potential flood source (river, dam, levee, precipitation). The deep borehole site surface facilities would be located in an area where the lowest floor of the structure, including subsurface floors, would be above the level of the 500-year floodplains. All facilities, including their basements, would be sited in an area above the 100-year floodplain.

Surface Water Quality. The quality of surface water across the nation is very diverse, affected by both natural processes and human activities. The natural quality of surface water is determined largely by the quality of its primary groundwater source, which is affected by the types of rocks through which the water moves and by various chemical processes. Absorption of atmospheric gases and assimilation of runoff and direct discharges further account for water quality differences throughout various potential generic deep borehole sites.

The range of surface water quality conditions that would be found at a generic deep borehole site is presented in Table 3.10.4–1. The amount of dissolved minerals in water (measured as dissolved solids) is a general indicator of overall inorganic water quality and, as shown in the table, could range from 10 to 174 mg/l (10 to 174 ppm). Iron and manganese could exceed water quality criteria. Nitrogen and phosphorus, which are major nutrients, contribute to the eutrophication of streams and lakes. Eutrophic waters are rich in nutrients that cause excessive growth of aquatic plants (for example, algae). Several forms of nitrogen are found in natural waters. Most common are the nitrate, nitrite, and ammonia ions. As shown in Table 3.10.4–1, nitrogen concentrations could range from 0 to approximately 2 mg/l (0 to 2 ppm), and phosphorus concentrations could range from 0 to 0.29 mg/l (0 to 0.29 ppm). The upper limits are more common in areas where there is considerable farming and soils are more likely to erode.

Table 3.10.4–1. Summary of Typical Surface Water Quality at the Generic Deep Borehole Complex Site

Parameter	Unit of Measure	Water Quality Criteria and Standards[a]	Water Body Concentration High	Water Body Concentration Low
Alkalinity	mg/l	NA	140	0
Alpha (gross)	pCi/l	15[b]	1.3	<0.4
Ammonia	mg/l	NA	0.25	0
Beta (gross)	pCi/l	50[c]	4.5	0.5
Calcium	mg/l	NA	9.9	0.8
Chloride	mg/l	250[d]	3.54	0.2
Chromium	mg/l	0.1[b]	0.04	0
Conductivity	µmhos/cm	NA	340	30
Dissolved oxygen	mg/l	>5.0[e]	14	6
Iron	mg/l	0.3[d]	1.5	0.02
Lead	mg/l	0.015[b]	0.013	0
Magnesium	mg/l	NA	9.3	0.5
Manganese	mg/l	0.05[d]	0.06	0
Nitrogen (as NO_2/NO_3)	mg/l	NA	2.13	0
pH	pH units	6.5-8.5[d]	8.5	6.3
Phosphorus	mg/l	NA	0.29	0
Sodium	mg/l	NA	20	0.7
Strontium-90	pCi/l	400[f]	0.33	0.01
Suspended solids	mg/l	NA	67	1
Temperature	°C	NA	35	0
Total dissolved solids	mg/l	500[d]	174	10
Uranium, Total	mg/l	0.02[c]	0.00019	0.00017
Zinc	mg/l	5.0[d]	0.6	0

[a] For comparison only.
[b] National Primary Drinking Water Regulations (40 CFR 141).
[c] Proposed National Primary Drinking Water Regulations; Radionuclides (56 FR 33050).
[d] National Secondary Drinking Water Regulations (40 CFR 143).
[e] Varies with pH and temperature.
[f] DOE DCG for water (DOE Order 5400.5). Values are based on a committed effective dose equivalent of 100 mrem per year; however, because the drinking water maximum contaminant level is based on 4 mrem per year, the number listed is 4 percent of the DCG. [Text deleted.]

Note: NA=not applicable; µmhos/cm=micromhos per centimeter.
Source: DOD 1993a.

Surface Water Rights and Permits. Surface water rights concerning the water body closest to the deep borehole site could range from not being an issue (because the site does not withdraw or discharge to a surface water body, or asserts its federally reserved water withdrawal rights), to impairment of designated uses.

Discharge of a pollutant to surface water requires a permit under the NPDES. NPDES permits include effluent limitations specifying the maximum concentrations of specific pollutants that may be present in discharge water.

Groundwater. Because of their characteristic remoteness, many government facilities use groundwater from onsite wells for their primary water supply. Groundwater could be used alone during construction and operations or could be mixed with either surface water or treated reclaimed wastewater.

The proposed deep borehole site could also be located in an area with undeveloped groundwater reserves, in underlying geologic strata, that are capable of providing an adequate supply of good quality water. Site-specific hydrogeologic data would be required to evaluate the groundwater availability.

The near-surface aquifer beneath the generic deep borehole site could occur under confined to unconfined conditions. Depth to groundwater could range from 1 to 200 m (3.3 to 656 ft). Recharge could occur primarily from rainfall and surface water seepage. Common ranges of hydraulic characteristics of aquifers are presented in Table 3.10.4–2.

Table 3.10.4–2. Common Ranges of Hydraulic Characteristics of Aquifers

Characteristic	Range of Conditions Low	High
Transmissivity (l per day/m)	46	46,200,000
Hydraulic conductivity (l per day/m^3)	0.0008	7,500
Recharge rate (cm/yr)	0.0025	50.8
Well yield (l/minute)	38	75,700

Source: DOD 1993a.

Aquifer classification beneath the generic deep borehole site could range from a sole-source, federally protected, or EPA Class I aquifer (an aquifer which is required to supply 50 percent or more of the drinking water for that area and for which there are no reasonable available alternative sources should the aquifer become contaminated) to a Class III aquifer (an aquifer not considered a potential source of drinking water and of limited beneficial use because the salinity is greater than 10,000 mg/l (greater than 10,000 ppm) or the groundwater is otherwise contaminated beyond levels that can be removed using reasonable methods of public water supply treatment). Most aquifers found at government-operated facilities are Class II aquifers, which are current or potential sources of drinking water.

Groundwater Quality. Groundwater quality of the near-surface aquifer in the generic site area could range from good to poor. Groundwater that would occur at the emplacement zone depth would be brine. Characteristics of this water are high salinity (indicative of long-term isolation from the biosphere), low carbonate concentrations, slightly basic and reducing geochemistry, and low thermal gradient.

Groundwater Availability, Use, and Rights. Groundwater availability could range from not an issue (because the site does not withdraw groundwater) to critical groundwater overdraft and low surface water availability relative to demand. Critical is defined as more than 1,893 million l/day (500 million gal/day) of overdraft (VDL 1990a:725). Overdraft of groundwater occurs when water is withdrawn from sources that cannot be renewed or is withdrawn more quickly than it can be recharged.

Groundwater rights for a generic deep borehole site could range from absolute ownership rule to appropriation. Under the absolute ownership rule, the owners of land overlying a groundwater resource are allowed to withdraw unlimited water from their wells for whatever purpose they choose. Under the appropriation doctrine, all water is declared to be public and subject to appropriation on the basis of the "first in time, first in right" principle and control of the well use is usually accomplished by permits.

3.10.5 Geology and Soils

Geology. The deep borehole site could be located in a variety of geologic settings within the contiguous United States, provided the primary deep borehole site criterium, isolation from the biosphere, can be maintained for geologic times. Two key conditions for isolation from the biosphere would be geologic stability and the very low hydraulic efficiency of potential conduits (fractures, faults) to prevent pathways for transport of disposed materials to the surface.

Possible geologic terrains could range from interior basins to stable continental crust. Surficial material could range from desert sands to glacial tills. Coastal margins, volcanic zones, and seismically active zones are, by definition, unstable and would not represent optimal locations for the deep borehole site. The topography of the deep borehole site would range from flat to hilly; areas of high relief could result in large hydraulic head differences and deep circulation. Table 3.10.5–1 illustrates some of the principal advantages and disadvantages associated with the different types of candidate geologic media.

Soils. The deep borehole site may be located in areas where the predominant soil types range from clays to sands. These soils can range from poorly- to well-drained soils. Soil erosion from past land uses, if any, can range from slight to severe. The soil erosion potential can range from slight to severe in those areas with slopes greater than 25 percent and which have been eroded in the past. Wind erosion potential can range from low to high. The soils shrink-swell potential can range from low to severe.

Table 3.10.5–1. Attributes of Different Types of Geologic Media

Medium Type	Advantages	Disadvantages	Analysis
Plutonic/Metamorphic "Basement" Rocks (for example, granite)	Salinity increases with depth; fewer fractures at depth; mechanically strong, impermeable matrix; occurs in sufficiently thick sections; many locations with large areal extent.	Limited data on conditions at depth, may be structurally complex.	No disqualifiers, potential host rock.
Tuffs (consolidated volcanic ash)	High compressive strength; high sorptivity.	Columnar joints; fractures and cavities, water may induce geochemical changes; limited geologically old occurrences (fails tectonic stability test); vertical section discontinuous; may have insufficient depth.	Not suitable due to tectonic instability and vertical discontinuity.
Rock salt (evaporite)	Isolated from aquifers; low interstitial water content; self-healing fractures due to plasticity.	Interbedded rock layers in bedded salt could act as fluid conduits, brine pockets could migrate; drilling difficulties due to plasticity; holes may close before emplacement due to plastic flow; may not be thick enough; not as old as basement rock implying less stability; mobile salt (domes) are unstable.	Probably not suitable for borehole due to unfavorable mechanical properties.
Anhydrite (evaporite)	Chemically stable; little interstitial water; hydration induced swelling may reduce permeability.	Brittle and easily fractured; not self-healing; massive swelling during hydration causes fractures and borehole instability; may not be thick enough; not as old as basement rocks implying less stability; limited areal extent.	Probably not suitable due to unfavorable mechanical properties.
Sedimentary rocks (shales)	Low interstitial permeability; high sorptivity.	Flows plastically under high stresses, may lead to borehole instability; highly fractured; not as old as basement rocks implying less stability; vertically discontinuous; may have conductive interbeds.	Probably not suitable due to vertical discontinuity and vertical fractures.
Mafic lavas (flood basalts)	Low matrix permeability; high compressive strength.	Limited occurrences, may imply tectonic instability; vertically discontinuous; interbeds may be efficient transport routes.	Probably not suitable due to vertical discontinuity and implied tectonic instability.
Unconsolidated sediments (alluvium)	Moderate to high sorptive capacity; effective radionuclide barriers.	Geologically very young implying instability; high potential for erosion or continued tectonic movements; may not be thick enough; may be too conductive.	Unsuitable due to young age and implied tectonic instability.

Source: LLNL 1996i:1.

3.10.6 BIOLOGICAL RESOURCES

Terrestrial and Aquatic Resources

The description of terrestrial and aquatic resources has been divided into natural habitats and migratory birds. In each case, an overview of these resources is given for the area within which the generic deep borehole site may be sited.

Natural Habitats. The following description characterizes the principal vegetation types that could be found at a potential deep borehole site and is based on *Fundamentals of Ecology* and *The Study of Plant Communities: An Introduction to Plant Ecology* (Odum 1971a:377-403; Oosting 1956a:269-377). The principal vegetation types are defined by their climax vegetation (vegetation that develops following an extended time without major disturbance), a useful method of describing terrestrial resources, since vegetation types are comprised of similar groupings of flora and fauna. Although these vegetative types are a terrestrial resource classification system, the discussion of each addresses characteristic aquatic resources in the same geographical area.

Most areas have been subjected to substantial human disturbance over the past centuries, even though vegetation types are characterized by their climax vegetation. These areas now largely support successional vegetation, which can include grasses and forbs, shrubs and saplings, or forest cover comprising species other than those of the climax vegetation. Each vegetation type displays its own characteristic patterns of succession. Additionally, the boundary between any two is often a blend of characteristics from both types. The following principal vegetation types could be found at a generic deep borehole site.

Northern Coniferous Forest. Northern coniferous forest is common across much of Canada and Alaska, but within the type of area being considered for a deep borehole complex occurs only in the northern New England States. Climate is severe, with a short growing season and moderate precipitation. The principal evergreen species present in this forest include red spruce and balsam fir, which often form dense canopies under which little understory vegetation can grow. Paper birch, poplar, and aspen are common deciduous trees on disturbed sites. Animals found in northern coniferous forests within New England include moose, beaver, porcupine, boreal chickadee, red-breasted nuthatch, a variety of warblers, ring-necked snake, smooth green snake, green frog, and spotted salamander. Reptiles and amphibians are not as common in this vegetation type as in those that occur in more southerly latitudes. Aquatic habitat includes streams and lakes; bogs also commonly occur in the northern coniferous forest.

Hemlock-Hardwood Forest. Hemlock-hardwood forest is found in the northeastern and north-central part of the type of area under consideration for a deep borehole complex. This region is typified by long, cold winters and a short growing season. Although this is a northern forest type, it occurs at higher elevations along the Appalachian Mountains as far south as northern Georgia. Important tree species include hemlock, white pine, basswood, American elm, white ash, and red oak. Hemlock-hardwood forests support a diversity of animals, including red squirrel, snowshoe hare, ruffed grouse, pine siskin, and red crossbill. Reptiles and amphibians are not as numerous in this community type as in more temperate areas. The common garter snake, painted turtle, and chorus frog are found in hemlock-hardwood forests. Fast-moving streams occur within mountainous portions of this vegetation type, while lakes are common within those portions of the region that were glaciated.

Deciduous Forest. Deciduous forest occurs in most of the eastern third of the type of area under consideration for a deep borehole complex and is characterized by a moist, temperate, seasonal climate. The canopy of a deciduous forest is typically dominated by two or three species of trees. Common trees include oak, hickory, beech, and maple. A patchy to well-developed understory tree layer is found, and shrubs are common. The deciduous forest supports a variety of animal life, including the white-footed mouse, eastern gray squirrel, raccoon, gray fox, whitetail deer, black bear, wood thrush, ovenbird, downy woodpecker, worm-eating warbler, rat snake, eastern ribbon snake, American toad, and green frog. Streams and rivers are abundant in deciduous forest and include a number of major river systems, such as the Ohio.

Grassland. Grassland occurs in much of the central portion of the area under consideration. The climate is characterized by pronounced seasonality with respect to rainfall and temperature. Climax vegetation is characterized by grasses and other herbaceous plants, because there is insufficient rainfall to support forest communities. Because of the naturally fertile, nearly level soil, much of this vegetation type has been converted to farmland for producing grains and providing pasture for cattle. Fauna of grassland communities include the black-tailed prairie dog, thirteen-lined ground squirrel, horned lark, ring-necked pheasant, greater prairie chicken, prairie kingsnake, rat snake, western box turtle, chorus frog, and Great Plains toad. Playa lakes to the south and prairie pot holes to the north are important habitats for waterfowl and a number of other species of wildlife. Perennial and intermittent streams and small lakes characterize the aquatic resources of this vegetation type.

Desert. Desert occurs in much of the southwestern and western portion of the type of area under consideration for a deep borehole complex and is characterized by a scarcity of rainfall (less than 25 cm [9.8 in]) or rainfall that is very unevenly distributed. Vegetation is sparse and consists mainly of shrubs and rapidly growing annuals. During the short periods of rainfall, a large number of grasses and forbs briefly appear. Although the environment is harsh, the desert supports a variety of fauna, including the bighorn sheep, mule deer, black-tailed jackrabbit, mountain lion, coyote, javelina, golden eagle, greater roadrunner, Gambel's quail, desert tortoise, and various species of lizards and snakes. Aquatic resources are generally limited to intermittent streams and washes.

Rocky Mountain Forest. Rocky Mountain forest encompasses a number of vegetation types due to changes in environmental factors with altitude. This results in the zonation of plant communities, reflecting rapid altitude changes over short distances. A single mountainous area can feature four or five vegetation zones within a change of elevation of several thousand meters. The flora and fauna of each zone are often similar to those previously described (such as desert, grassland, deciduous forest, and northern coniferous forest). However, the zones are not always continuous nor are they always all present. Near the northern limits of this complex, the lower zones run out and the upper zones are found at relatively low altitudes. Southward, all zones are found at successively higher altitudes. Diverse freshwater aquatic habitats and species are associated with this vegetation complex.

Migratory Birds. Migratory birds include both waterfowl and the numerous other birds (for example, passerine species) that travel between breeding and wintering grounds. These species are dependent on the presence of adequate habitat along their migratory routes to provide both resting and feeding areas. The importance of these species has been recognized by the passage of the *Migratory Bird Treaty Act*. This act seeks to prevent the killing of migratory birds and the destruction of their eggs and nests.

Waterfowl. The four migratory waterfowl flyways (Pacific, Central, Mississippi, and Atlantic) represent some of the traditional routes for fall and spring migration of certain North American migratory waterfowl such as geese, swans, and cranes. While the Central and Mississippi flyways are entirely within the type of area being considered for a deep borehole complex, the Pacific and Atlantic flyways are only partially within the site area. To maintain migratory waterfowl populations, an adequate amount of open space, open water, and wetlands is necessary for foraging and refuge during migration. Wetlands also provide important breeding habitat for migratory waterfowl. Major breeding areas occur in the northern portion of the deep borehole site area. During the winter months, waterfowl migrate to the southern United States and Central America, where they congregate in wetland regions.

Other Migratory Birds. The flyways discussed above are a simplified method of describing migration paths used by certain types of waterfowl. Many other species of migratory birds follow different north-south routes across the type of area being considered for a deep borehole complex, often changing their migration paths from one year to the next. Typically, smaller birds such as rails, flycatchers, most sparrows, warblers, vireos, thrushes, and shorebirds migrate at night. Day migrants include large and small birds such as gulls, pelicans, hawks, swallows, nighthawks, and swifts (FWS 1979a:20,21,61).

Wetlands

Although wetlands occur across the entire type of area being considered for a deep borehole complex, they are most prevalent in the mid-Atlantic, southeast, south-central, and north-central portions of the site area. Major types of wetlands occurring in the site area include tidal salt marshes, freshwater marshes, northern peatlands, shrub swamps, and riparian forested wetlands. Wetlands serve important functions, including maintaining water quality, controlling floodwaters, stabilizing shorelines, and providing animal habitat and recreational uses such as hunting and fishing. Wetlands are also important in providing habitat for aquatic organisms and migratory birds, as well as for threatened and endangered plants and animals. Since it is difficult to protect surface waters and wetlands during construction drilling operations necessary for a deep borehole, wetlands typically would be avoided during selection of potential borehole drilling sites.

Threatened and Endangered Species

Threatened and endangered species could be present in each of the principal vegetation types discussed above. Over 750 threatened and endangered species occur in the United States (FWS 1995a:1-35). Endangered plants and animals often rely on sensitive environments such as wetlands for habitat. Critical habitats, geographical areas that are considered essential to the conservation of a species and that could require special management considerations or protection, can be designated and protected under the ESA. Protection of threatened and endangered species and their habitat is important for maintaining biodiversity, which is essential for full ecological functioning.

3.10.7 CULTURAL AND PALEONTOLOGICAL RESOURCES

Prehistoric Resources. Prehistoric resources could be affected by the construction and operation of a deep borehole site. These resources may include objects, sites, or districts. Archaeological sites can include villages and campsites. Sites may yield artifacts such as stone tools and associated manufacturing debris and ceramic potsherds. Some sites may be eligible for inclusion on the NRHP.

Historic Resources. Historic resources that could be affected by construction and operation of a deep borehole site include subsurface remains of human occupation such as structural foundations of buildings, important paths or roads, and cemeteries. Some standing buildings such as commercial structures and residences may also be considered historic resources.

Native American Resources. Native American resources that could be affected by construction and operation of a deep borehole site may include sites, areas, and materials important to Native Americans for religious or heritage reasons. Sacred sites may include cemeteries, plant communities, mountains, paths, or geographical spaces that are socially identified and circumscribed. Some Native American groups could be affected and may need to be consulted if a specific site is chosen.

Paleontological Resources. Paleontological resources that could be affected by construction and operation may include fossil remains of extinct plants or animals, some rare. They can include poorly known fossil forms, well-preserved terrestrial vertebrates, unusual depositional contexts, assemblages that contain a variety of fossil forms, or deposits recovered from poorly studied regions or in unusual concentrations.

3.10.8 SOCIOECONOMICS

The generic deep borehole site could potentially affect the socioeconomic environment of an REA or an ROI. The characteristics of the REA, ROI, and communities are dependent upon geographic location. Employment and income in the economic area would be based upon industry interaction and linkages in the region. The anticipated residential distribution of project-related employees and their families would determine the ROI, and the ROI would contain all principal jurisdictions and school districts for community services likely to be affected by the proposed activity. Local transportation would consist of the existing principal road, air, and rail networks required to support the project activities.

Potential locations for a deep borehole have not been identified, so the affected environment cannot specifically be determined. The deep borehole complex would require a buffer zone of approximately 2,000 ha (4,900 acres). If the deep borehole complex were located in a largely uninhabited region, the majority of the workforce might choose to live in a more densely populated region and endure a longer commute to work. There is also the possibility of limited housing availability (and residential utilities), which could cause workers and their families to move to the more densely populated areas. It is also possible that the REA and the ROI could comprise uninhabited areas and small rural communities or contain different community types. The range of potential community types could be categorized as uninhabited regions, rural areas and small rural communities, and medium-size communities.

Uninhabited regions include unpopulated portions of the United States and Federal lands that have been set aside and are not developable. Economic activity in these regions is nonexistent. The primary issue is the availability and suitability of infrastructure and transportation networks to support the project activities.

Rural areas and small communities include areas or communities with populations of less than 50,000. These are small business centers that have a small workforce with little diversification of industries and employment. Public services, infrastructure, and transportation networks are generally limited, but capacities would vary with each location. These areas generally have small, specialized economies and relatively large basic sectors dependent on export activities.

Medium-size communities include areas with a city of at least 50,000 in population or an urbanized area of at least 50,000 with a total metropolitan population of 100,000. These communities usually operate as local or regional centers for economic activity. A local center usually has the largest community within a radius of approximately 80 km (50 mi); however, a larger regional or nationwide center is nearby for wholesaling, finance, and activities that do not involve the consumer directly. A regional center usually would be the largest community within a radius of 160 to 240 km (100 to 150 mi). The number of employment sectors is higher than in small communities, and economic relationships would exist between only a limited number of industries. Public services, transportation networks, and other infrastructures would tend to be more extensive than in smaller communities.

Communities of each category typically differ in terms of size and diversification. The vulnerability or susceptibility of a local community to changes in the economic base depends, in large part, on the strength of its economic base, as indicated by its number of employment sectors, its diversification of employment sectors, its pool of available labor, and its degree of inter-industry linkages. Inter-industry linkage is an economic relationship between two or more industries within the same market. A well developed network of mutually supporting diversified industries insulates a local economy from factors outside the region and contributes to a strong economic base. Communities with strong diversified economic bases are not affected by socioeconomic change as much as communities that have bases that rely on a single basic employment sector.

3.10.9 PUBLIC AND OCCUPATIONAL HEALTH AND SAFETY

Radiation Environment. Major sources and levels of background radiation exposure to individuals in the vicinity of a generic deep borehole site are shown in Table 3.10.9–1. Annual background radiation doses to individuals are expected to remain constant over time. The total dose is expected to change as the population size changes. Background radiation doses are unrelated to any site operations that may exist at a potential deep borehole site.

Table 3.10.9–1. Sources of Radiation Exposure to Individuals in the Vicinity, Unrelated to Operation at the Generic Deep Borehole Complex Site

Source	Effective Dose Equivalent (mrem/yr)
Natural Background Radiation[a]	
Cosmic and cosmogenic radiation	27 to 39
External terrestrial radiation	28 to 59
Internal terrestrial radiation	39 to 40
Radon in homes (inhaled)[b]	200
Other Background Radiation[b]	
Diagnostic x rays and nuclear medicine	53
Weapons test fallout	<1
Air travel	1
Consumer and industrial products	10
Total	359 to 403

[a] Based on annual reports for illustrative sites and EPA 1981b.
[b] NCRP 1987a.
Note: Value for radon is an average for the United States.

Releases of radionuclides to the environment from operations at generic deep borehole sites provide another source of radiation exposure to individuals in the vicinity of the sites. Types and quantities of radionuclides released from operations in 1993 at sites at developed locations that have current nuclear activities (refer to Sections 3.2.9 through 3.7.9), which could be typical of a generic deep borehole are listed in the 1993 annual environmental reports for those sites. The range of doses to the public resulting from these releases is presented in Table 3.10.9–2. The doses fall within radiological limits (DOE Order 5400.5) and are small in comparison to background radiation. The releases listed in the 1993 reports were used in the development of the reference environments (No Action) radiological releases and resulting impacts in the year 2005 (Sections 4.3.3.1.9 and 4.3.3.2.2.9). For the generic deep borehole site that is not developed and has no current nuclear activities, there would be no radionuclide releases or doses in the past. For these sites, the No Action releases and doses in the year 2005 are assumed to be zero.

Based on a risk estimator of 500 cancer deaths per 1 million person-rem to the public (Section M.2.1.2), the fatal cancer risk to the maximally exposed member of the public due to radiological releases from operations in 1993 at the generic deep borehole sites addressed in Sections 3.2.9 through 3.7.9 is estimated to range from 2.9×10^{-11} to 1.5×10^{-6}. That is, the estimated probability of this person dying of cancer at some point in the future from radiation exposure associated with 1 year of deep borehole site operations ranges from about 3 chances in 100 billion to less than 2 chances in 1 million. (Note that it takes several to many years from the time of exposure to radiation for a cancer to manifest itself.)

Table 3.10.9–2. Radiation Doses to the Public From Normal Operation at the Generic Deep Borehole Complex Site in 1993 (Committed Effective Dose Equivalent)

	Atmospheric Releases		Liquid Releases		Total	
Members of the General Public	Standard[a]	Actual	Standard[a]	Actual	Standard[a]	Actual
Maximally exposed individual (mrem)	10	5.8×10^{-5} to 1.4	4	0 to 0.60[b]	100	5.8×10^{-5} to 3.0[c]
Population within 80 km[d] (person-rem)	None	1.4×10^{-4} to 26	None	0 to 2.0	100	1.4×10^{-4} to 28
Average individual within 80 km[e] (mrem)	None	5.0×10^{-7} to 0.030	None	0 to 0.0023	None	5.0×10^{-7} to 0.032

[a] The standards for individuals are given in DOE Order 5400.5. As discussed in that order the 10 mrem/yr limit from airborne emission is required by the CAA, the 4 mrem/yr limit is required by the SWDA, and the total dose of 100 mrem/yr is the limit from all pathways combined. The 100 person-rem value for the population is given in proposed 10 CFR 834 (58 FR 16268). If the potential total dose exceeds the value, it is required that the contractor operating the facility notify DOE.

[b] These doses are mainly from drinking water and eating fish.

[c] This total dose includes 1 mrem/yr from direct radiation exposure.

[d] In 1993, this population ranged from 21,750 to 880,000.

[e] Obtained by dividing the population dose by the number of people living within 80 km of the site.

Note: Data from annual environmental reports for those illustrative sites discussed in Sections 3.2.9 through 3.7.9; all of these sites have nuclear activities. For potential sites having no nuclear activities, the doses would be zero.

Based on the same risk estimator, a range of 7×10^{-8} to 0.013 excess fatal cancers is projected in the populations living within 80 km (50 mi) of these same illustrative sites from normal operations in 1993. To place these numbers into perspective, they can be compared with the numbers of fatal cancers expected in these populations from all causes. The 1990 mortality rate associated with cancer for the entire U.S. population was 0.2 percent per year (Almanac 1993a:839). Based on this mortality rate, the number of fatal cancers expected during 1993 from all causes ranged from 44 to 1,760 in the population living within 80 km (50 mi) of the borehole site. These numbers of expected fatal cancers are much higher than the estimated range of 7×10^{-8} to 0.013 of fatal cancers that could result from operations at generic deep borehole sites in 1993. The risks and numbers of expected fatal cancers from radiation from generic deep borehole sites that currently have no nuclear activities would be zero.

Site workers receive the same dose as the general public from background radiation, but they also receive an additional dose from working in the site facilities. Table 3.10.9–3 presents the range of the average worker, maximally exposed worker, and total cumulative worker dose to workers from operations in 1992 at a generic site at developed locations that presently have nuclear activities (Sections 3.2.9 through 3.7.9). These doses fall within radiological regulatory limits (10 CFR 835). Based on a risk estimator of 400 fatal cancers per 1 million person-rem among workers (Section M.2.1.2), the number of excess fatal cancers to workers from site operations in 1992 is estimated to range from 8.0×10^{-4} to 0.14. For generic deep borehole sites at undeveloped locations with no nuclear activities, the occupational radiological exposure would be zero.

A more detailed presentation of the radiation environment, including background exposures and radiological releases and doses, is presented in the 1993 annual environmental reports for the active DOE sites, representative of developed locations. The concentrations of radioactivity in various environmental media (that is, air, water, and soil) in the regions of the sites (onsite and offsite) are also presented in these reports (see Sections 3.2.9 through 3.7.9).

Chemical Environment. The background chemical environment important to human health consists of the atmosphere, which may contain hazardous chemicals that can be inhaled; drinking water, which may contain hazardous chemicals that can be ingested; and other environmental media with which people may come in contact (for example, surface waters during swimming and soil through direct contact or via the food pathway).

Table 3.10.9–3. Radiation Doses to Workers From Normal Operation at the Generic Deep Borehole Complex Site in 1992 (Committed Effective Dose Equivalent)

Occupational Personnel	Onsite Releases and Direct Radiation	
	Standard[a]	**Actual**
Average worker (mrem)	ALARA	2.6 to 27.3
Maximally exposed worker (mrem)	5,000	660 to 3,000
Total workers[b] (person-rem)	ALARA	2 to 350

[a] DOE's goal is to maintain radiological exposure as low as reasonably achievable.

[b] The number of badged workers in 1992 ranged from 780 to 19,500.

Source: 10 CFR 835; DOE 1993n:7.

The baseline data for assessing potential health impacts from the chemical environment are those presented in Sections 3.2.3 through 3.7.3.

Effective administrative and design controls that decrease hazardous chemical releases to the environment and help achieve compliance with permit requirements (that is, air emissions and NPDES permit requirements) contribute toward minimizing potential health impacts to the public. The effectiveness of these controls is verified through the use of monitoring information and inspection of mitigation measures. Health impacts to the public may occur during normal operations at the deep borehole site via inhalation of air containing hazardous chemicals released to the atmosphere by site operations. Risks to public health from other possible pathways, such as ingestion of contaminated drinking water or direct exposure, are low relative to the inhalation pathway.

Baseline air emission concentrations for hazardous chemicals and their applicable standards are included in the data presented in Sections 3.2.3 through 3.7.3. These concentrations are estimates of the highest existing offsite concentrations and represent the highest concentrations to which members of the public could be exposed. These concentrations are in compliance with applicable guidelines and regulations. Information about estimating health impacts from hazardous chemicals is presented in Section M.3.

Exposure pathways for workers at a generic deep borehole site during normal operation may include inhaling the workplace atmosphere and direct contact with hazardous materials associated with work assignments. The potential for health impacts varies from facility to facility and from worker to worker, and available information is not sufficient to allow a meaningful estimation and summation of these impacts. However, workers are protected from hazards specific to the workplace through appropriate training, protective equipment, monitoring, and management controls. Site workers are also protected by adherence to OSHA and EPA standards that limit workplace atmospheric and drinking water concentrations of potentially hazardous chemicals. Appropriate monitoring that reflects the frequency and amounts of chemicals utilized in the operational processes, ensures that these standards are not exceeded. Additionally, DOE requirements ensure that conditions in the workplace are as free as possible from recognized hazards that cause or are likely to cause illness or physical harm. Therefore, worker health conditions at a generic deep borehole site are expected to be substantially better than required by the standards.

Health Effects Studies. Specific locations for the deep borehole complex must be designated before any reviews of epidemiologic studies in the areas can be conducted.

Accident History. Since there is no deep borehole site in operation, there is no site accident history.

Emergency Preparedness. The generic deep borehole site would have an emergency management program that could be activated in the event of an accident. The program would be compatible with all other Federal, State, and local plans and be thoroughly coordinated with all interested groups. The program would be modified, as necessary, to accommodate deep borehole operations.

3.10.10 WASTE MANAGEMENT

This section describes the range of waste management activities and regulatory framework that could exist at a generic deep borehole site. The volume of waste generated by existing DOE sites varies greatly. Existing DOE sites also have a wide range of capability in the "cradle-to-grave" management of the various categories of wastes. Sites such as INEL, Hanford, and SRS have an extensive onsite treatment, storage, and disposal capability for most waste categories. Whereas, sites such as Pantex have a limited treatment and storage capability, and with the exception of a landfill for construction debris, have no onsite disposal capability. For generic deep borehole sites that would not be on or near a DOE facility, it is highly unlikely that there would be any ongoing waste management activities, except for a possible sanitary wastewater treatment facility or sanitary landfill. There are no regulations that clearly pertain to the disposal of surplus Pu material into a deep borehole. However, the regulations that would govern the waste management activities in support of the deep borehole are well-defined. A general discussion follows to describe the range of waste management activities if a deep borehole were located on or near a DOE facility.

Spent Nuclear Fuel. There would be no spent nuclear fuel associated with a deep borehole site.

High-Level Waste. There would be no HLW associated with a deep borehole site.

Transuranic Waste. Transuranic wastes are unique to DOE. Most TRU waste exists in a solid form and is comprised of protective clothing, paper trash, rags, glass, miscellaneous tools, and equipment that have become contaminated with TRU radionuclides. Liquid TRU wastes are generated from the chemical processing for recovery of Pu or other TRU elements. TRU wastes are managed in accordance with DOE Order 5820.2A. TRU wastes are to be processed and packaged to meet the WIPP WAC or alternate treatment level and placed in interim storage while awaiting the availability of a Federal repository. Mixed TRU waste must also meet the requirements of RCRA as outlined in 40 CFR 260. The generation of TRU waste at DOE sites ranges from 0 to 638 m^3/yr (0 to 835 yd^3/yr) and from 0 to 225 m^3/yr (0 to 294 yd^3/yr) for mixed TRU (DOE 1994d:122,124).

Low-Level Waste. Low-level waste is generated at more than 30 different DOE sites and is disposed of at Hanford, NTS, INEL, ORR, SRS, and LANL. LLW is usually rags, papers, filters, tools, equipment, and discarded protective clothing contaminated with radionuclides. In accordance with DOE Order 5820.2A, LLW must be characterized with sufficient accuracy to permit proper segregation, treatment, storage, and disposal. Waste acceptance criteria are established for each LLW treatment, storage, and disposal facility. For the 30 sites that generate LLW, the generation ranged from a few cubic meters (few cubic yards) to 14,090 m^3/yr (18,430 yd^3/yr) (DOE 1994d:145). The average land usage factor for the six DOE LLW disposal facilities ranges from 3,400 to 29,700 m^3/ha (1,800 to 15,700 yd^3/acres) (DOE 1994d:141,152).

Mixed Low-Level Waste. Mixed LLW at DOE sites includes a variety of contaminated materials, including air filters, cleaning materials, engine oils and grease, paint residues, photographic materials, soils, building materials, and plant equipment being decommissioned. In accordance with the *Federal Facility Compliance Act* of 1992, each DOE site that generates, stores, or treats mixed LLW has developed a Site Treatment Plan. The Site Treatment Plan lays out the development of technologies and capacities needed to treat mixed LLW to the standards required by RCRA. With approval of the plans, the regulatory agency issued an order requiring compliance with the approved plan. For those DOE sites that generated mixed LLW in 1993, the generation ranged from less than 1 m^3 (1.3 yd^3) to 1,900 m^3 (2,485 yd^3) (DOE 1994d:241).

Hazardous Waste. Hazardous wastes generated by DOE facilities include solvent rags, analytical laboratory chemicals, photographic shop wastes, spent solvents, waste oil, and paint wastes. Hazardous wastes are managed in accordance with RCRA as outlined in 40 CFR 260. Most DOE sites ship their hazardous wastes offsite to commercial RCRA-permitted facilities under contract, using DOT-registered transporters.

Nonhazardous Waste. The DOE generates the same kinds of liquid and solid nonhazardous wastes that any industrial facility would generate. Liquid nonhazardous wastes may undergo a wastewater treatment process before discharge to a publicly owned treatment works or surface waters. Wastewater treatment processes may include a neutralization of acidic or basic wastewater or flocculation/clarification. These liquid wastes are regulated by the CWA and are treated and discharged in accordance with NPDES permits and other state and local guidelines. Solid nonhazardous wastes are disposed of in onsite sanitary landfills that are owned and operated by DOE or shipped offsite to municipal landfills for disposal. The operation and management of solid nonhazardous wastes are regulated under the provisions of RCRA, Subtitle D.